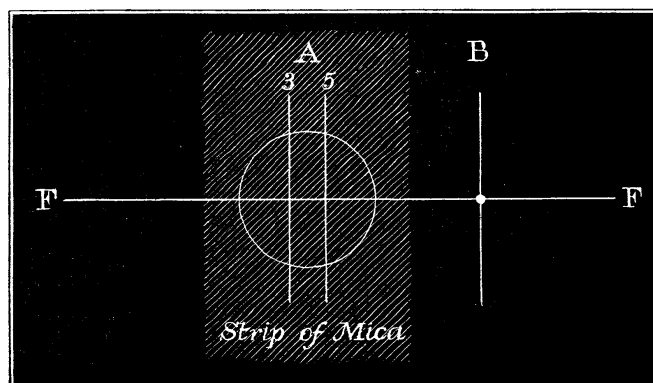


Micrometer Measurements of Phobos, the Inner Satellite of Mars, during the Opposition of 1894. By H. F. Newall, M.A.

The following measurements of the inner satellite of *Mars* were made during the opposition of 1894 with a filar micrometer on the 25-inch refractor of the Cambridge Observatory.

The satellite could on most occasions be seen with the planet in full sight in the field, but it was found to be easier to make the measurements when the main glare of the planet was subdued by a slip of mica, tolerably thickly blackened by smoke, fixed to the eyepiece in such a way that the mica was as close to the plane of the webs as possible consistently with safety to the webs. No illumination of the field or webs was used, the satellite being so close to the planet that there was enough light in the background to make the webs visible.

There are in the micrometer two frames, A and B, each carrying a set of webs, one moved by a screw A, the other by screw B. The measurements of distance were all made with the screw B. The value of one revolution has been taken as $5''.911^*$, determined from measurements of the separation (about $270''$) of two stars in the *Pleiades*, a provisional value of the separation being taken from Elkin's measurements.



The only webs on frame A with which we have here to do are two parallel webs, A_3 and A_5 , separated by a fixed interval of about $8''$, and a fixed web, FF, which is parallel to the axes of the screws A and B, and perpendicular to A_3 and A_5 . The middle point of the part of FF between A_3 and A_5 is moved by movements of the screw A and of the micrometer box on its slipping piece so as to be at the centre of the position circle. When this adjustment was completed, neither screw A nor the

* This value may require a slight alteration; it will be given when the sources of some curious discrepancies which have occurred between the results of determinations by different methods are more thoroughly understood. I am indebted to Professor Turner for his kindness in measuring a large number of photographs of the Pleiade with a view of giving a reliable value for the separation of the stars I used in one of my methods.

slipping piece was moved during the measurements. *Mars* was brought by moving the telescope into such position that equal segments were cut off by A_3 and A_5 , and that FF bisected the disc; the slow motion in R.A. is actuated electrically.

The position circle is turned till FF also passes through the satellite, and B is moved up to bisect the satellite.

The procedure finally adopted was—

- (i) To centre the planet on FF and A_3A_5 .
- (ii) To turn FF to bisect the satellite, or rather to put FF a little ahead of the satellite in its apparent orbit.
- (iii) To move up B to bisect the satellite when it reached FF.
- (iv) To begin counting with the chronometer when the double bisection was satisfactory.
- (v) To look back to the planet to verify the centering.
- (vi) To read the chronometer, if centering and bisection were both satisfactory.
- (vii) To read the micrometer and position circle at leisure, or to start again afresh if the requirements were not satisfied.

It was decided to adopt this somewhat troublesome method of procedure rather than to make use of the convenient slipping piece and take several readings of distance and position angles separately, because the first attempts to make measurements showed how rapid the motion of the satellite was, and it seemed best to concentrate effort and care on a single set of simultaneous values of position angle, distance, and epoch.

It will be seen that there are fifty-four observations recorded, sixteen referring to western elongations on three nights, the remaining thirty-eight referring to eastern elongations on three nights.

A correction for phase was applied, based on the assumption that the measurements referred to the centre of gravity of the illuminated disc of *Mars*:

$$\Delta s = \frac{4a}{3\pi} \sin^2 \frac{E}{2} \cos (p - Q),$$

where a (apparent diameter), E (areocentric angle between Earth and Sun), p (position angle), and Q (position angle of greatest defect in illumination) had values assigned by interpolation from Marth's valuable ephemerides (*Monthly Notices*, vol. liv. pp. 394 and 557). The interval between the fixed wires A_3 and A_5 was small enough compared with the apparent diameter to make it probable that the "centre of gravity" correction would be nearer the mark than a correction based on the idea that the observed centre was midway between the terminator and the limb.

The phase correction was not applied to the position angle, such correction seldom amounting to $0^\circ.01$. Nor was any correction for refraction made.

I am indebted to my assistant, A. W. Goatcher, for efficient help rendered during these observations.

1894. Oct. 19	Greenwich Mean Time. h m	Observed Distance. "	Correction for Phase. "	Corrected Distance. "	Distance at Distance Unity. "	Position Angle. °	
Oct. 19	11 1'39	31'25	...	...	13'59	...	Observations interrupted by cloud. Mean of two obsns. 228'63, 228'03.
	16 36	28 82	...	...	12'54	...	
	23 33	28'66	...	...	12'47	...	
	25 55	28'53	...	...	12'41	...	
	46 27	...	...	...	...	228'33	
	53 25	24'93	...	...	10'85	...	
	57 24	24'02	...	...	10'47	...	
	11 20 31	27'97	...	...	12'51	...	
	22 81	28'68	...	...	12'82	233 48	
	32 78	27'49	...	...	12 29	231'98	
Nov. 6	12 2 69	26'84	...	...	12'00	224'57	Observations stopped by cloud.
	10 44 66	22'98	-0'13	22'84	11'02	...	
	52'64	23'57	-0'13	23'44	11'31	...	
	55'63	24'35	0'13	24'21	11'69	...	
	57 62	24'93	0'13	24'79	11'97	...	
	...	...	...	...	...	64'55	
	11 3'61	26'59	0'13	26'46	12'77	...	
	10 09	26'35	0'13	26'22	12'65	...	
	12 59	26'69	0'13	26'56	12'82	...	
	13 59	26'69	0'13	26'55	12'82	...	

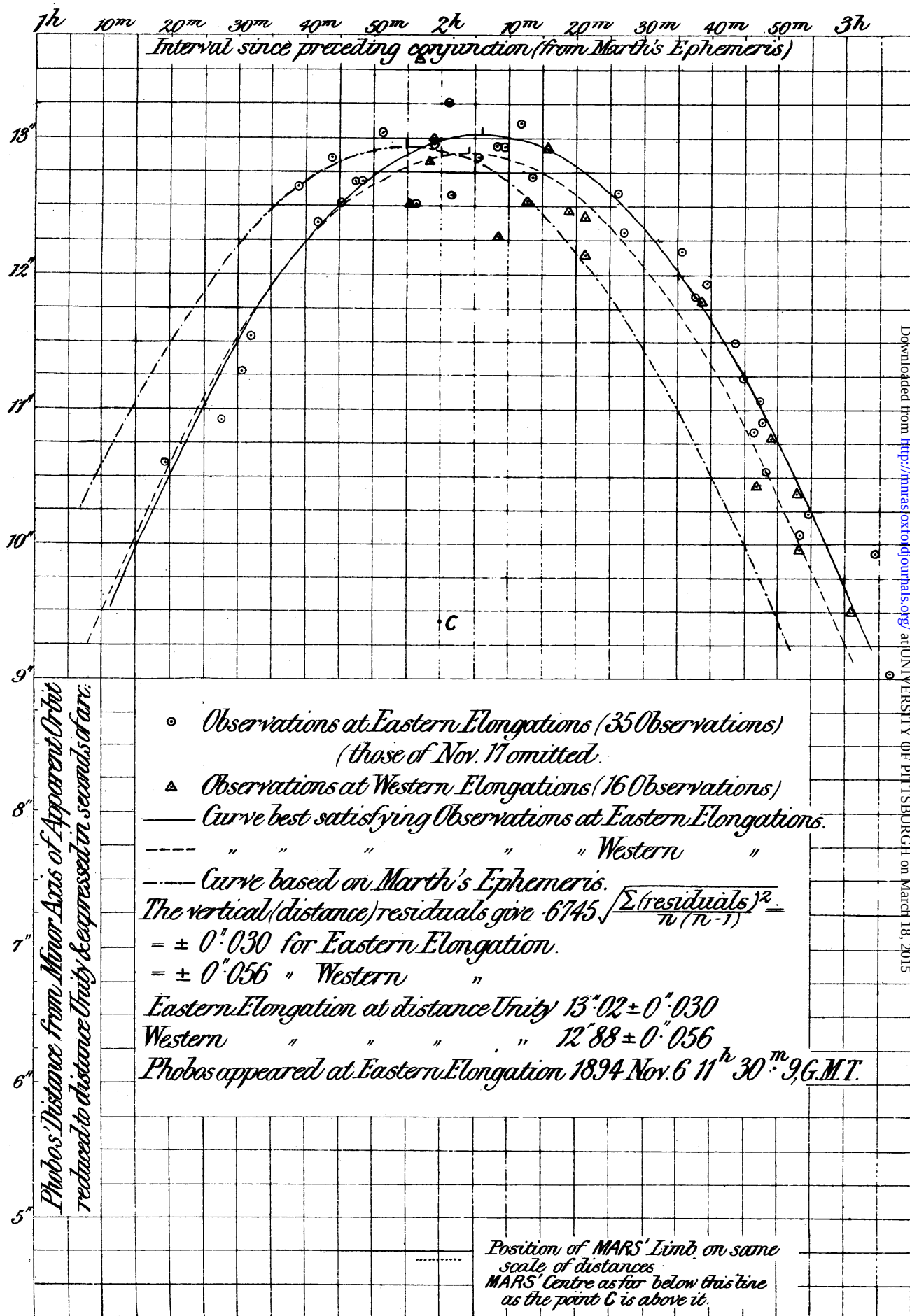
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1894. Nov. 6	Greenwich Mean Time. h m	Observed Distance. "	Correction for Phase. "	Corrected Distance. "	Distance at Distance Unity. "	Position Angle. °	
	11 21.56	26.36	0.13	26.23	12.66	...	
	26.55	26.55	0.13	26.41	12.75	...	
	29.56	...	...	...	...	54.33	
	33.53	26.90	0.13	26.77	12.92	...	
	38.02	26.48	0.13	26.35	12.72	...	Observations interrupted by cloud.
	48.49	...	...	...	...	48.69	
	50.98	26.38	0.13	26.25	12.67	...	
	52.48	25.83	0.13	25.69	12.40	...	
	59.46	25.55	0.13	25.42	12.27	...	
	12 2.35	24.86	0.13	24.72	11.94	...	
	4.34	25.02	0.13	24.89	12.02	...	
	5.44	...	...	...	...	40.10	
	8.40	24.87	0.13	24.75	11.95	...	
	9.40	24.31	0.13	24.18	11.67	...	
	11.40	23.45	0.13	23.32	11.26	...	
	12.40	23.59	0.13	23.46	11.33	...	
	13.40	22.79	0.13	22.67	10.94	...	
	19.40	22.16	0.13	22.03	10.64	...	Observations stopped by clouds.
	29.38	21.45	0.13	21.32	10.30	...	
Nov. 15	9 22.66	24.12	-0.25	23.86	12.53	65.43	

	Greenwich Mean Time.	Observed Distance.	Correction for Phase.	Corrected Distance.	Distance at Distance Unity.	Position Angle.	
	h m	"	"	"	"	°	
1894. Nov. 15	9 25.95	24.81	-0.25	24.57	12.89	60.78	Telescope reversed.
	33.93	25.11	0.25	24.86	13.05	58.74	
	40.91	24.92	0.25	24.68	12.95	55.68	
	43.90	25.50	0.25	25.25	13.26	57.40	
	47.39	24.71	0.25	24.46	12.84	54.51	
	51.38	24.85	0.25	24.60	12.92	55.41	
	54.57	25.33	0.24	25.09	13.17	51.10	
	10 28.88	22.31	0.22	22.09	11.60	39.23	
	35.46	20.43	0.22	20.21	10.62	38.16	
	48.65	18.53	0.22	18.31	9.62	36.29	
Nov. 17	7 16.29	24.08	-0.27	23.80	12.74	63.80	Bad seeing.
	30.26	22.28	0.27	22.01	11.78	59.59	
	40.09	24.03	0.27	23.76	12.15	57.12	
	9 19.85	23.41	+0.29	23.71	12.97	236.71	
	36.83	23.34	0.29	23.63	12.93	233.17	
Nov. 19	42.54	22.05	0.28	22.34	12.23	228.88	Observations stopped by cloud. Seeing very variable: often necessary to wait for many minutes.
	10 8.30	19.60	0.27	19.87	10.88	219.62	
	15.02	18.86	0.26	19.12	10.47	218.15	
	21.92	18.28	0.26	18.53	10.15	215.59	



A simple graphical method of getting a survey of the observed places suggested itself. The corrected values were reduced to distance unity, and the intervals that had passed since the last conjunction of the satellite with the planet, as deduced from Marth's Ephemeris, were determined. All the observations were thus available for plotting on a single curve. It was decided to deal with distances measured parallel to the major axis of the apparent orbit, and therefore a correcting factor $[\cos \{p \sim (P \pm 90)\}]$ was applied to the reduced distances. If the orbit were circular, the curve obtained by plotting the time and the distance parallel to the major axis would be a curve of sines. It was expected that a suitable sine-curve-template moved about among the plotted observations would reveal discrepancies. It appears that the time devoted would probably have been better spent on the laborious method of least squares. It is, however, perhaps not without interest to show the results of plotting the observations (see Plate 6), for they at any rate bring to light that the adopted periodic time of *Phobos* needs a slight correction, *Phobos* being between nine and eleven minutes later than Marth's Ephemeris.*

It is not improbable that the error in the time of elongation of *Phobos* has been accumulating since one of the oppositions shortly after its discovery. Such a belatedness as nine minutes shows either that we are not entitled to use the three figures after the decimal point in the seconds in the periodic time, or that a change in period has occurred.

It seems almost unjustifiable to compare the results of these scanty observations with those of the splendid set of measurements recently published by W. W. Campbell (*Ast. Journ.* vol. xv. p. 1). There appears in my observations evidence of differences between eastern and western elongation-distances of the same kind as those which Professor Campbell's observations establish; it should, however, be noted that my observations at western elongation were not so numerous or satisfactory as those at eastern elongation. Professor Campbell notes that his observations show that *Phobos* is $6^m \pm$ later than Marth's Ephemeris.

* Having experienced the great serviceableness of these valuable ephemerides, perhaps I may be allowed to suggest that a short prefatory note detailing the data used and the sources from which they are derived would be very useful.